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SEMAUTOMATION OF BASIN AND BORDER IRRIGATION

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Basin and border irrigation systems use relatively large supply streams which require precise set times to optimize irrigation efficiency and to prevent dike overtopping and excessive runoff. During the past decade, these systems have greatly benefitted from advancements made in land grading technology using laser-guided equipment. Although this has increased distribution uniformity, reliably predicting the time required for water to advance to the end of a field is still often difficult. Advance time is influenced by variable water deliveries, variable soil intake rates within a given field and throughout the season, and by different stages of crop growth. Thus, the irrigator must make frequent trips to the field to observe the water's advance, which is particularly inconvenient at night. These problems can be reduced by semi-automating the irrigation system and by using sensors located near the lower end of a field to provide feedback to terminate irrigation of a given land. Semiautomation is usually preferred because of its simplicity and lower cost compared to more sophisticated systems. Semiautomated systems require manual input to either turn water into the system or to reset or reposition the structures and/or control devices. The next step toward system improvement during the coming decade is greater use of automated structures and controls to provide greater convenience for the irrigator, labor savings, and increased irrigation efficiency.

Several different gate configurations and controls which are currently being field tested in both a level basin and a border system are described in this paper.

SYSTEM DESCRIPTION

Basin and border irrigation systems are used under many different conditions and the water may be supplied from either open channels or buried pipelines. Various gate styles and methods of automating these systems are discussed by Humpherys (1986). Most basin and border systems in the United States use low-gradient supply channels because fields that are most feasibly irrigated with these systems have very little side slope. Thus, check gates in the head ditch are usually spaced some distance apart with multiple irrigation sets in between. This requires dual-function field turnout gates between ditch checks that first open to admit water to the field and then close to terminate irrigation of a field segment. Single-function gates which either open or close are also used as described later.

The concrete-lined supply ditch for the level basin system in which gates are being tested near Delta, Utah, serves basins on both sides and has a zero slope with a 0.06 m (0.2 ft) drop between each four basins—two on each side. Basins on the west side of the ditch are lower in elevation than those on the east side and have pipe outlets near the bottom of the ditch while the rectangular outlets on the east side are near the top of the ditch, Fig. 1. The supply stream size for the 4 Ha (10 acre) basins varies from about 225 l/s (8 cfs) to 300 l/s (11 cfs). Water is distributed simultaneously through four field turnouts or ditch outlets into each basin. Both single and dual-function gates are used.

The border system being tested (Eskdale, Utah) uses a concrete-lined ditch with two 38 mm (15 in) diameter pipe outlets for each border. The ditch is on a mild slope and uses a check gate between each border.

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FIELD TURNOUT GATES

All of the turnout gates being evaluated require manual reset and are released by either electric solenoids or trip cords.

Rectangular Drop-Closed Gates

Rectangular gates were designed for installation in existing basin turnout openings and replaced the original manual slide gates. The gates differ from those used previously in other systems because the hinges are designed to provide a closing moment on the gate panel. This improves gate sealing and prevents leakage, particularly with shallow upstream water depths which do not provide sufficient force to hold the gate tightly closed. The gate latch is designed to be easily released and to withstand wind forces when the gate is in its latched, open position, as shown in the foreground of Fig. 1. Sealing around the edges of the gate was also improved by using an extruded rubber seal strip with a curved lip. The gates generally had zero leakage and provided a tighter seal than the original manual slidegates, which pleased the farmer.

Drop-Closed Gates for Pipe Outlets

These gates were designed to retrofit new or existing pipe turnouts for semiautomation. A gate for the level basin system, shown in the background of Fig. 1, is mounted on a bracket attached to the edge of the concrete ditch lining. A foot pad on the portion of the bracket that extends into the ditch is rigidly attached to the ditch lining with construction cement. The original slide gates formerly used at the turnout openings were removed. The metal-ring seats for the original gates also provide seats for the drop-closed gates. A rubber seal on the gate lid in contact with the seat provides a very tight seal which is better than that of the original gate. A similar gate was designed for the larger-sized pipe turnouts of the border system.

Butterfly Gates

These new style, dual-function gates first open to admit water to the field and then close to terminate irrigation. Each gate consists of a sheet metal panel which rotates about a horizontal pivot axis located at the center of the panel. The steel-pipe shaft, about which the gate rotates, is mounted at the top of the rectangular turnout opening. The gate has two latches which allows it to rotate from its closed-to-open-to closed positions through 180 degrees as the latches are sequentially released. When the first latch is released, the gate is pushed open by water on its up-stream side to begin irrigation; the gate then rotates 90 degrees where it is restrained by a second latch. A gate in the level basin system is shown in its open, horizontal position in Fig. 2. One side is weighted heavier than the other to provide a closing moment so that when the second latch is released to end irrigation, the gate acts similar to a drop-closed gate and rotates 90 degrees to its second closed position. When closed, water pressure holds the gate panel tightly against the gate frame. The gate is manually reset by rotating it backwards to its original closed position.

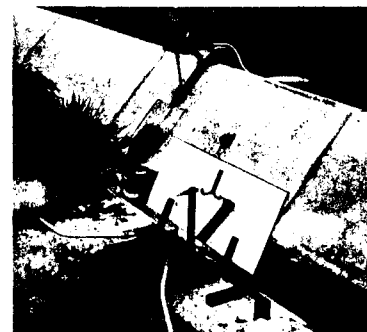


Fig. 1 Drop-closed gates for pipe and rectangular outlets.

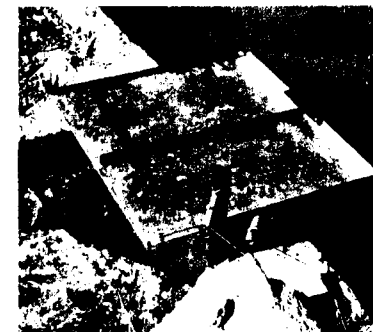


Fig. 2 Butterfly dual-function gate.

Combination Gate

A combination, dual-function gate was tested as an alternative to the butterfly gate. This gate consists of a drop-open gate and a drop-closed gate mounted on the same frame. In operation, the drop-open gate mounted on the downstream side of the frame is released to begin irrigation and the drop-closed gate on the upstream side of the frame is released to terminate irrigation. Functionally, there is little difference between the combination and butterfly gates; they both performed satisfactorily in the basin system. One advantage of the combination gate is that it can generate a greater pull force to operate a trip-cord release system while the butterfly gate, in some respects, is simpler to construct.

DITCH CHECK GATES

Center-of-Pressure Gates

Trapezoidal, center-of-pressure check gates are used between consecutive sets of the level basin system, and as shown in Fig. 3, between each pair of turnouts in the border system. These gates are larger than any used in previous systems and are designed to open at a given water depth by using water which spills from an overflow notch. The water's weight in a container on the back side of the gate is used to activate a gate latch. The gate pivots on a horizontal pipe shaft located at approximately the one-third point vertically and is designed to open automatically when the water depth exceeds its balanced-force depth. At this depth, water forces on the gate above and below the axis are approximately equal. By using the center-of-pressure principle, the gate's latch is greatly simplified because the force that it must resist is only that created by the incremental water depth between the gate's normal tripping depth, if it were not restrained by a latch, and the actual depth of water at the lip of the spill spout. This type of gate release is effective and reliable.

Linear Actuator-Operated Gate

Manually-operated jack gates are commonly used both as field turnout gates and as check gates in basin systems where relatively large ditches and stream sizes are used. These gates can be automated by using a linear actuator to raise and lower the gate panel. A linear actuator was installed on a check gate located in the head ditch between a pair of level basins as shown in Fig. 4. The actuator¹ is powered by a 12-volt battery and has a 61 cm (24 in) stroke with internal limit switches to turn the actuator off at each end of its stroke. It has a load capacity range from 2,200 kg (1,000 lb) to 3,850 kg (1,750 lb) at corresponding load currents ranging from 15 to 22 amp.



Fig. 3 Center-of-pressure check gate.

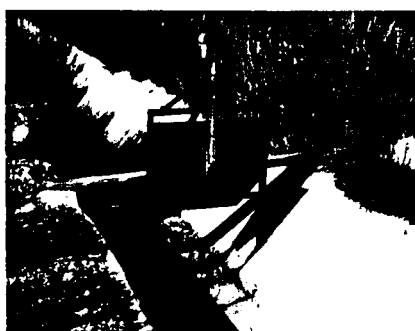


Fig. 4 Battery-powered linear actuator mounted on a jack gate.

¹Burr Engineering and Development Corp., Battle Creek, MI 49016.

Trade and company names are provided for the benefit of the reader and do not imply endorsement or preferential treatment of the brand or product noted.

Corresponding travel speeds vary from 6 to 8 mm/s (0.25 to 0.32 in/s). The actuator has more than adequate lift capacity since the maximum lift required to raise most jack gates is about 990 kg (450 lb) as reported by Dedrick and Erie (1978). The actuator control unit, mounted on the gate frame, consists of a DPDT toggle switch for manual operation and a 3PDT relay for controlling the gate with a water sensor.

SYSTEM CONTROL

Trip-Cord Gate Release System

Large borders and level basins often have multiple turnouts to accommodate the large irrigation streams that are used. In an automated system, all of the turnout gates which serve one basin or border must be released or actuated at the same time. This can be done electrically; however, a mechanical trip-cord system developed for this purpose proved more reliable and costs less.

This system consists of a 3 mm (1/8 in) polypropylene trip cord installed in a 19 mm (3/4 in) diameter, 1,400 kpa (200 psi) PVC pipe buried along the ditchbank. A 25 mm (1 in) PVC pipe was also used as an alternative in part of the system. A larger pipe may be needed if rodent activity is severe. The cord has a short, miniature, stainless steel cable attached to each end which, in turn, is attached to the activating gate on one end and the latch of the activated gate on the other end as shown in Fig. 5. Thus, when one gate closes, it pulls the cord to release the next gate in the sequence. The first gate of a series is released by an electric solenoid activated by a controller. The ends of the trip cord and cables are enclosed in 13 mm (1/2 in) either flexible aluminum, EMT or vinyl electrical conduit attached to the PVC pipe so that the entire trip-cord is enclosed for protection. Flexible vinyl conduit is used where salts are present which would attack the metal conduits. Each end of the PVC pipe is anchored with a mound of concrete.

The solenoid-released gates can be controlled by mechanical or electrical timer-controllers or by feedback from sensors located near the end of the field with their associated controllers.

Water Sensor

A low-cost water sensor was developed to determine the arrival of the advancing water front at a given point in the basin. The sensor provides an electrical signal which is used to terminate irrigation when the water front approaches the downfield end of the basin. The sensor body consists of nominal 30 mm (1 1/4 in) PVC pipe and fittings cemented to the top of a 100 mm (4 in) sewer and drain (S & D) PVC cap which forms the sensor base as shown in Fig. 6. A pair of 3 mm (1/8 in) stainless steel welding rod electrodes extend from inside the base into the sensor body where they are connected to a monostable interface on a printed circuit board. The electrode shield shown in Fig. 6 isolates the electrodes to prevent water condensation from short-circuiting them. The monostable circuit opens the transmission circuit after water contacts the electrodes to prevent battery drain while the electrodes remain wet. It automatically resets itself between irrigations when the electrodes become dry.

The sensor was initially used with infrared (IR) telemetry which transmitted the gate activating signal to a receiver on the ditch bank at the head of the field (Humpherys, 1988). However, to minimize the cost of either equipping additional basins with telemetry stations or to eliminate the need to move the telemetry system from basin to basin, the farmer-cooperator opted to use buried communication wires from the sensor to its associated controller at the turnout gate. One set of buried wires serves two basins (or borders)--one on each side.

A pneumatic sensor system was developed which would allow one IR transmitter/receiver station to serve multiple basins or borders (Humpherys and Fisher, 1987); however, it has not yet been adequately tested.

Water Sensor Controllers

Water sensor controllers receive a transmitted signal from a sensor and respond by closing the turnout gates which serve that basin (or border). The controller consists of a silicon controlled rectifier (SCR), capacitor, switch, and 12-volt lantern or rechargeable battery which are enclosed in a surplus military ammo box (Humpherys, 1988).

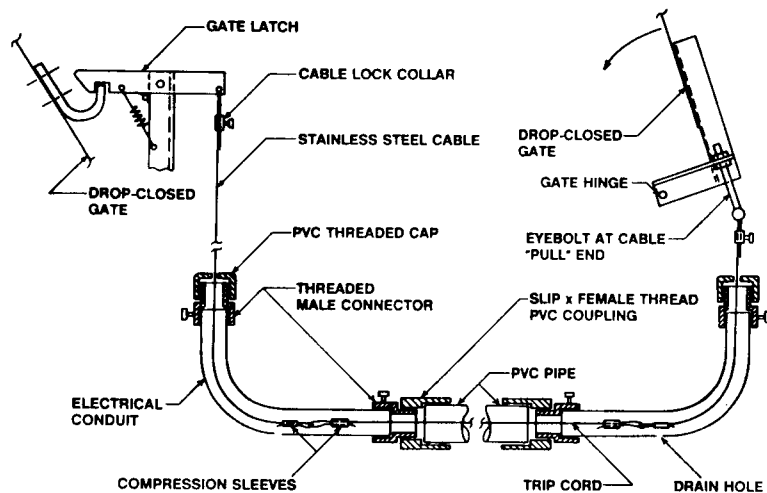


Fig 5 Diagram of a trip-cord system for releasing semiautomated gates.

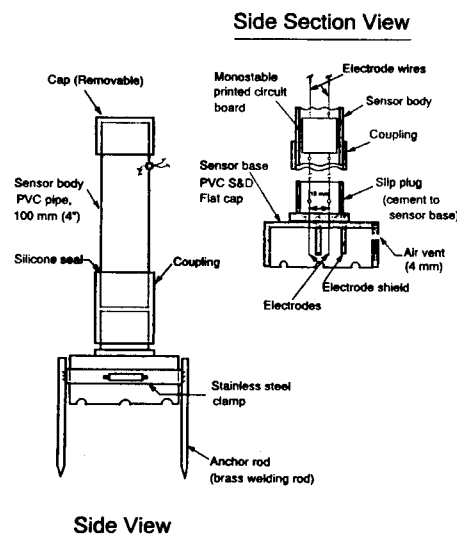


Fig 6 Diagram of a water sensor used for feedback control of an irrigation gate.

SYSTEM OPERATION

Level Basin System

All of the gates are manually reset prior to an irrigation. During irrigation, water is first diverted to a low-elevation basin through pipe outlets located near the bottom of the ditch. When water reaches a sensor located about 0.8 of the downfield length of the basin, the sensor provides a signal to close the turnout gates to terminate irrigation of that basin. Upon receiving the signal, the sensor controller energizes a solenoid which releases the first of four gates which, in turn, closes the other three gates serving that basin through a trip-cord gate release system. The water level in the supply ditch then rises and flows through rectangular turnouts into the basin on the opposite side of the ditch where the irrigation sequence is repeated. When a center-of-pressure check gate is used in the supply ditch between basin pairs, the water level rise resulting from the turnout gates closing is used to open the check gate; this allows irrigation of the next downstream pair of basins to begin. When a linear actuator-operated jack gate is used as a check gate, a water sensor signal from the second basin is used to activate the linear actuator which then opens the check gate. Irrigation proceeds in this manner from basin to basin until all eight basins of the 32.4 Ha (80 acre) field are irrigated.

Water tends to flow through the rectangular turnout openings of one high-elevation basin during irrigation of the basin on the opposite side of the ditch. For this basin, dual-function gates are used which remain closed during irrigation of the first basin.

Border System

This system will be operated for the first time in 1990. Each border is served by two ditch turnouts which are equipped with drop-closed gates. The first gate of the two is released by a mechanical timer. The first gate then releases the second gate with a trip cord. The resulting water level rise in the supply ditch is used to open a center-of-pressure check gate located between each border.

SUMMARY

Field tests of semiautomated gates and controls in a level basin irrigation system and a border system are underway. Gates and their associated controls that were developed and are being tested include: (1) drop-closed gates for both rectangular and pipe-type field turnouts, (2) a trip-cord gate release system for closing multiple gates simultaneously, (3) butterfly and combination type turnout gates, (4) center-of-pressure and linear actuator-operated check gates, and (5) water sensors for providing feedback for irrigation control along with their associated controllers. Operation of the integrated systems with their various components was described. Use of these gates and controls results in greater operator convenience and labor savings and can increase irrigation efficiency.

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